

INDIGENOUS PRIMITIVE CARBON IN EUCRITES AND DIOGENITES. Monica M. Grady^{1,2}, I.P. Wright² and C.T. Pillinger², ¹Department of Mineralogy, The Natural History Museum, Cromwell Road, London SW7 6BD, UK (M.Grady@nhm.ac.uk), ²Planetary Sciences Research Institute, The Open University, Walton Hall, Milton Keynes MK7 6AA, UK

Eucrites (both cumulate and non-cumulate) and diogenites are related to each other by a number of geochemical parameters, most diagnostically by oxygen isotope systematics. The meteorites are fragments of rocks produced by complex processes of partial melting, fractional crystallisation, thermal metamorphism, brecciation and mechanical mixing. They are anhydrous materials, which crystallised at low pressures under moderately reducing conditions. Eucrites have been subdivided into several chemical groups, but are still mainly brecciated pyroxene-plagioclase basalts, whereas diogenites are orthopyroxenites. Both eucrite and diogenite rock types display igneous textures characteristic of their formation: the former are rapidly cooled melts representative of extrusive (non-cumulate eucrites) or shallow intrusive (cumulate eucrites) origin, the diogenites are brecciated plutonic igneous cumulates.

Despite the close relationship in major element chemistry and oxygen isotopic composition between cumulate and non-cumulate eucrites, rare earth element data have been interpreted as indicating the two eucrite types were derived from separate sources, and might not be related [e.g. 1, 2], a theory supported by re-interpretation of eucrite crystallisation ages [3]. Xenon isotope chronology [4] also distinguishes between the formation ages of equilibrated and unequilibrated eucrites: the former (the cumulate eucrites) are older than the latter (non-cumulate) by < 80 Ma. At least three separate source areas on a single body have been proposed for the eucrites; dio-

genites have a similar fission-xenon age to the cumulate eucrites [4].

Since eucrites and diogenites crystallised *in vacuo* they are well degassed of volatiles. Notwithstanding this, carbon is present and has presumably played an active role in influencing the redox conditions prevailing during formation. The actual form in which carbon occurs in this suite of meteorites is unknown, but by analogy with terrestrial basalts, may be present as a coating of elemental carbon along grain boundaries, and also as dissolved CO/CO₂/CO₃²⁻ in silicate minerals [5]; phosphates, present as fluorapatite and merrillite [6] are also possible sinks for CO₂/CO₃²⁻ [7].

The carbon contents and isotopic compositions of four eucrites and four diogenites have been determined. Stepped heating in an oxygen atmosphere was employed to convert selectively different carbonaceous materials to carbon dioxide gas at various temperatures. This technique successfully distinguishes between terrestrial contaminants and indigenous carbon. Eucrites and diogenites contain *ca.* 10-30 ppm of indigenous carbon, with $\delta^{13}\text{C}$ ranging from -29‰ to -19‰. The data demonstrate that the carbon contents of basaltic achondrites determined previously [8], *ca.* 500 - 5000 ppm, are too high by 1-2 orders of magnitude. The reason for this discrepancy is the failure of the earlier study to take account of terrestrial contamination, which is by far the major carbon component in these samples.

Diogenites have slightly lower carbon abundances than the eucrites, with higher $\delta^{13}\text{C}$. The relative enrichment in ¹³C is consistent with carbon isotope fractionation during

degassing of CO or CO₂ from the mafic silicates during metamorphism or annealing, as the minerals soften at high temperatures. However, three out of the four diogenites studied also contain a discrete carbonaceous component which combusts across the temperature range from 700°C to 800°C, and has an isotopic composition $\sim -27\text{‰}$ to -25‰ . This material is presumably graphite coating the silicate grains, preferentially assimilated into the mafic melt as elemental carbon, and unaffected by the extended annealing period experienced by the diogenites. It is possible that this component might host the indigenous primitive xenon recently identified in diogenites [4].

It has been proposed [e.g. 9, 10] that eucrites and diogenites were derived from a single source of primitive undifferentiated material through episodes of partial melting and remelting, followed by subsequent thermal annealing and brecciation. Eucrites are products of open-system melting of the source region at an early stage in its differentiation, whereas diogenites are slowly-cooled plutonic cumulates. More recent work implies that eucrites and diogenites formed from separate source regions, but still require a common parent [e.g. 11]. It is possible to rationalise carbon chemistry in the framework of these models of eucrite-diogenite development: the lower abundance and heavier isotopic composition of carbon in diogenites compared to the eucrites implies that carbon was degassed from the former. This is in keeping with the different thermal histories of the eucrites and diogenites: isotopic fractionation during open-system metamorphism or annealing results in the preferential loss of ¹²C-enriched carbon from the plutonic diogenites compared to the more rapidly-quenched eucrites, with the carbon being removed as CO or CO₂ from within

the silicate lattice as it softens or undergoes phase transitions. However, the isotopically light graphite present in the diogenites (3 - 5 ppm with $\delta^{13}\text{C} \sim -27\text{‰}$ to -25‰) as a discrete component superposed on the residual magmatic carbon might be a remnant primordial phase more readily assimilated into the mafic diogenites than the pyroxene-plagioclase eucrites. Extended annealing of the graphite would not result in significant oxidation of the carbon at the low $f(\text{O}_2)$ predicted for diogenite formation [12]. By analogy with chondritic meteorites, the graphite could be the host of the indigenous xenon present in low quantities in diogenites [4]. The absence of this graphite in eucrites might also explain the apparent absence of meteoritic xenon in these basalts.

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